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SUBJECT:

MECHANICAL DRAWING.

9

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Mechanical Drawing.

DRAWING PLATE, TITLE: DETAILS.

46. The first eight figures of this plate show the conventional methods of representing screws. The actual projection of a screw thread will be similar to the projection of the helix shown in Plate V; but, in order to save the time required to locate the points and trace in the curves, the following methods are universally used, except, perhaps, in the case of screws of very large diameter and pitch, drawn full size.

Fig. 1 represents a **single square-threaded screw** $1\frac{1}{2}$ inches in diameter, and $\frac{3}{8}$ inch pitch. To draw the screw, first draw the center line $m\,n$, and a line $A\,B$ at right angles to it. Make the distance $A\,B$ equal to the diameter of the screw, or $1\frac{1}{2}$ inches, and through the points A and B draw lines $A\,D$ and $B\,E$ parallel to the center line $m\,n$. Also lay off on the line $A\,B$ distances $A\,F$ and $B\,G$ equal to one-half of the pitch, and through the points F and G draw lines $F\,H$ and $G\,I$ parallel to the center line $m\,n$. These lines show the depth of the thread. On the line $A\,D$, lay off the width of the thread and of the groove, $A\,C$, $C\,J$, $J\,K$, etc., each equal to one-half of the pitch, or $\frac{3}{8} \times \frac{1}{2} = \frac{3}{16}$ of an inch. Draw the line $B\,C$, and through the points J, K, L, M, etc. draw lines parallel to $B\,C$. Draw faint pencil lines through the points C and P, J and Q, K and R, etc., to represent the back edges of the threads, and make the parts which are seen full lines; then draw the lines $T\,V$, $U\,W$, etc. The method of drawing the remainder of the screw, and

the reason for using the heavy shade lines, as shown, should be apparent without further explanation.

It will be noticed that the width of the thread and of the groove, measured parallel to the center line $m\,n$, and the depth of the thread, are all exactly the same; that is, they are each equal to one-half of the pitch. If a section were taken through the center line $m\,n$, the thread and groove would look like Fig. 71, a series of squares; hence the term *square thread*.

Fig. 2 shows a **double square-threaded screw** $1\frac{1}{2}$ inches in diameter, and with $\frac{3}{4}$ of an inch pitch. The reason for using a double thread is that if the single square thread were used, the depth would be so great as to weaken the bolt or rod on which it was cut, and render it unsafe for the purpose for which it was intended. To prevent this, either the diameter of the rod must be increased or the thread must be cut of the same depth and thickness as a thread of half the pitch, or, in this case, as if the pitch were $\frac{3}{4}$ of an inch $\times \frac{1}{2} = \frac{3}{8}$ of an inch, as in the preceding problem; another thread of the same size and pitch ($\frac{3}{4}$ of an inch) must be cut half-way between these first threads, thus giving a double thread. The pitch, or distance that the screw would advance in one turn, would be $\frac{3}{4}$ of an inch, the same as if it were a single-threaded screw of $\frac{3}{4}$ of an inch pitch, while the depth of the thread is only half as great.

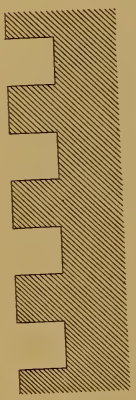

Fig. 71.

To draw it, proceed exactly as in the last figure. To get the direction of the line $B\,C$, which in this figure represents the projection of the bottom edge of the top of the thread, lay off $A\,C$ equal to one-half of the pitch, or $\frac{3}{4} \times \frac{1}{2} = \frac{3}{8}$ of an inch. and draw the line $B\,C$. The width of the threads and grooves, and also the depth of the threads, is one-fourth of the pitch, or $\frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$ of an inch.

Through the points K, L, M, etc. draw faint pencil lines $K\,X$, etc., to represent the back edges of the threads, and make those parts which are seen full lines. Through the point K draw a faint pencil line $K\,R$, at right angles to the center line $m\,n$, intersecting the line $F\,H$ in a, and draw the line $T\,a$, which

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represents the bottom of the thread. The remainder of the screw should now be drawn without any trouble.

Fig. 3 is a **single V-threaded screw** $1\frac{1}{4}$ inches in diameter and having 7 threads to the inch; that is, the pitch is $\frac{1}{7}$ of an inch. Draw a cylinder $1\frac{1}{4}$ inches in diameter, having $m\,n$ for the center line. Lay off $A\,B$, $B\,C$, $C\,D$, etc., each equal to the pitch, or $\frac{1}{7}$ inch. Do the same on the left-hand side. By the aid of the T square and 60° triangle make the angles $A\,O\,B$, $F\,O'\,G$, etc. The rest of the thread can be drawn by referring to the figure.

Fig. 4 represents a screw exactly like the preceding one, except that the thread is left-handed, instead of right-handed as in the previous case.

To ascertain whether a thread is left- or right-handed, hold the screw in such a position that its axis is horizontal. If the thread is right-handed, as it usually is, the angle which the edge of the thread makes with the horizontal on the right-hand side is obtuse; if left-handed, it makes an acute angle with the right-hand side of the horizontal. No further instruction should be necessary for drawing the thread.

Fig. 5 represents a **double V-threaded screw** $1\frac{1}{4}$ inches in diameter. It has $3\frac{1}{2}$ threads per inch; that is, the pitch is $1 \text{ inch} \div 3\frac{1}{2} = \frac{2}{7}$ inch. The same remarks regarding the drawing of it apply here that were used in describing Figs. 2 and 3.

Fig. 6 represents a section of a **brass nipple.** When the diameter of a nipple is given, the inside diameter is always meant, unless otherwise specially stated. The actual diameter of a nipple or pipe is very rarely given, but must be taken from printed tables. The *nominal diameter* of the nipple shown in the figure is 1 inch, but the actual inside diameter is 1.05 inches; from the table, the outside diameter is found to be 1.32 inches, making the thickness .135 of an inch. Owing to the thinness of the shell, pipe threads are finer than the threads on the same-sized rods. The coarsest pipe thread is 8 threads per inch. The number of threads per inch on the nipple shown is $11\frac{1}{2}$. The thread is tapered to make a tight fit, and the length of the threaded part on each end is $0.52 + 0.53 = 1.05$ inches, of which length the distance between a and b represents the

perfect thread, while from b to c the thread is chamfered ; that is, it dies out gradually. To draw the nipple, make a sectional view as shown. Draw a cylinder, having $m\,n$ as a center line 1.32 inches in diameter ; lay off the inside diameter equal to 1.05 inches, and draw $A\,B$ and $C\,D$. Now lay off the diameter $H\,K$ equal to 1.26 inches. Then lay off the distances $H\,J$ and $K\,L$, equal to $0.52 + 0.53 = 1.05$ inches ; join the points H and J, and K and L, by straight lines representing the top of the threads. Now on the center line $m\,n$, or on any line parallel to it, lay off a distance of 1 inch from the line $A\,C$ downwards. Divide this distance into $11\frac{1}{2}$ parts by means of the method given in problem 6, Art. **31.** Project the points just found upon $H\,J$, and, by means of the **T** square and 60° triangle, draw the threads from H to J as though all the threads were perfect. Draw the threads on $K\,L$ in the same manner, remembering that the divisions on $H\,J$ are to be advanced half a thread, as shown ; that is, the top of one thread and the bottom of the preceding thread on the other side will be on a horizontal line. Now lay off the distance $a\,b$ equal to 0.52 inch, and project it on lines drawn parallel to $K\,L$ and $H\,J$, and touching the bottom of the threads. From the points of intersection draw straight lines to J and L, in order to obtain the bottoms of the imperfect threads extending from b to c. Complete the rest of the drawing in the same manner.

Fig. 7 shows another method of representing a **V**-threaded screw. This method has the advantage of making a neat-looking drawing, and of being very rapid in delineation. The pitch is laid off as in the three preceding figures. The heavily shaded lines represent the bottom of the thread, and their lengths are determined by constructing an equilateral triangle on the pitch distance as shown, and limiting the line to distances between two corresponding vertexes of the triangle. The diameter of the screw is 1 inch, and the number of threads per inch is 8.

Fig. 8 represents the same screw shown in Fig. 7, but the lines indicating the bottom of the thread are left out altogether. This method is used on drawings where haste is necessary. Unless in very much of a hurry, the method shown in Fig. 7 is to be preferred. Ordinarily, when drawing screws as represented

by Figs. 7 and 8, it is not customary to lay off the pitch and the depth of the thread as above mentioned—the distances between the lines representing the threads are simply gauged by the eye; practice will enable this to be done very quickly and accurately.

Fig. 9 shows two views of a small **hand-wheel.** To draw it, locate the center O, and through O draw the center lines $t\,r$ and $m\,n$ at right angles to each other. From O as a center, with the compasses set to the radius of the wheel, or $3\frac{1}{4}$ inches, draw the outer circle of the rim; then, lay off the thickness of the rim, which is $\frac{5}{8}$ of an inch, and draw the inner circle. Through O, with the T square and 60° triangle, draw the center lines $A\,B$ and $C\,D$. With O as a center, draw two circles, one having a diameter of $\frac{5}{8}$ of an inch, to represent the hole, and the other a diameter of $1\frac{1}{4}$ inches, to represent the outside of the hub. To draw the arms, make the chords of the arcs $a\,b$, $c\,d$, etc. each $\frac{1}{2}$ inch long. Make the chords $h\,l$, $i\,k$, etc. each $\frac{3}{8}$ inch long, and draw $l\,b$, $h\,a$, $k\,d$, etc. With a radius equal to $\frac{1}{4}$ of an inch, describe the fillets, or arcs, $A'\,B'$, $C'\,D'$, etc. tangent to the arms at A', B', C', etc. With a radius equal to $\frac{1}{8}$ of an inch, describe the fillets or arcs tangent to the inside of the rim and to the arms. All of these arcs terminate at the point of tangency. The cross-sectioned part on the arm indicates that a cross-section taken at $E\,F$ would look as shown, that is, that the arm is elliptical.

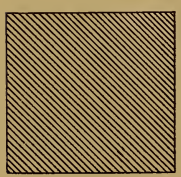
The other view shows a conventional method, largely used in drawing rooms, of indicating a section of the wheel. It is termed a conventional method because it would really be impossible to obtain a section like the one shown. Theoretically, the arm in this view should be sectioned, but, for convenience, a section is imagined to be taken through the rim and hub on the line $t\,r$, and the two arms are shown in projection as they appear on the line $m\,n$. Draw the center line $p\,q$ and the sections of the rim, as shown. Draw the arms from the dimensions given. Draw the hub as shown, using a radius of $\frac{5}{32}$ of an inch to draw the fillets or arcs tangent to $A\,B$ and to the arm; make $O'\,H'$ equal to $O\,H$ in the other view, and describe an arc through H' tangent to the two arcs just drawn,

which are tangent to AB and the arm. The rest of the drawing can be completed without further explanation.

Fig. 10 shows a **crank,** which should be drawn without difficulty from the dimensions given. The pin is forced in, and the end riveted over at AB, to prevent it from being pulled out.

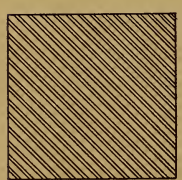
SECTION LINES.

47. The method ordinarily used for indicating the different materials by means of section lines is shown in Fig. 72, in a series of small squares drawn according to the usual method of sectioning the material named at each square.

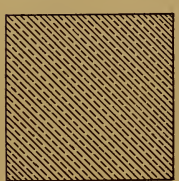


Cast iron, as mentioned before, is indicated by a series of parallel lines equally distant apart.

Wrought iron is sectioned in the same manner, except that every alternate line is shaded.

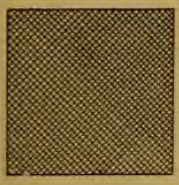


Steel is sectioned by drawing two lines close together, and the third line about $1\frac{1}{2}$ times as far from the second as the second is from the first, and repeating.



Brass is sectioned like cast iron, except that every other line is broken.

FIG. 72.



Babbitt metal is sectioned like cast iron —but in both directions, forming little squares.

Wood is sectioned by a series of rings and radiating lines like the cross-section of an oak tree.

FIG. 72.

SCALES.

48. When it is desired to make a drawing other than full size, special scales are used. Thus, suppose it is required to make the drawing $\frac{1}{4}$ size; then, 3 inches on the drawing would represent 1 foot on the object. Hence, if 3 inches are laid off and divided into 12 equal parts, each of these parts will represent 1 inch on the object. If these parts be subdivided into 2, 4, 8, etc. parts, each will represent $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, etc. of 1 inch on the object. A scale of this kind is called a **quarter scale,** or a **scale of 3 inches to the foot.** An **eighth scale,** or a **scale of $1\frac{1}{2}$ inches to the foot,** would be constructed in the same way, except that $1\frac{1}{2}$ inches would be laid off instead of 3 inches. These scales are written $3'' = 1$ ft., $1\frac{1}{2}'' = 1$ ft.

Fig. 73 shows the scale (12 inches long) with which the student should be supplied, and the manner of using it. One edge is divided the whole length into inches and sixteenths of an inch, and is used for full-size drawings. The other edge contains two scales, namely, $1\frac{1}{2}$ inches and 3 inches to the foot, indicated by the figures $1\frac{1}{2}$ and 3 at *A* and *B*. It will be noticed that on the scale of 3 inches to the foot the zero mark is at *C* instead of at *G*, as in full-size scales. It is put there for convenience in reading feet and inches at the same time. The figures indicating the number of feet on this scale are placed along the extreme upper edge at *D*, *E*, and *F*. To lay off 2 feet

$3\frac{3}{4}$ inches from some point, as *H*, towards another point, as *I*, place the scale on the point *H*, so that the 2-foot mark will fall on this point; then, from the zero mark, lay off $3\frac{3}{4}$ inches, as shown, locating the point *I*. *H I* will be 2 feet $3\frac{3}{4}$ inches long. The same remarks apply to the other scale of $1\frac{1}{2}$ inches to the foot. To draw to half size, or 6 inches to the foot, use the full-size scale, and remember that every $\frac{1}{2}$ inch on that scale corresponds to 1 inch on the object, that is, that every dimension is only half of the real length. To lay off $5\frac{7}{8}$ inches, lay off 5 half-inches and $\frac{7}{16}$ of an inch over; the result is a line $5\frac{7}{8}$ inches long to a scale of 6 inches to the foot.

FIG. 73.

If it is desired to draw to a scale of $\frac{3}{4}$ of an inch to the foot, or $\frac{1}{16}$ size, use the scale of $1\frac{1}{2}$ inches to the foot, halving all dimensions, as in the previous case of drawing to a scale of 6 inches to the foot with a full-size scale. It sometimes happens that a draftsman is obliged to make a scale, when the size of his plate is limited and a general drawing of some object is desired. By *general* drawing is meant a complete view of the object in plan, and also one or two elevations. In such a case one scale may be too large to enable the drawing to be made on a sheet of the required size; another scale may make it too small to show up well. For example, an $\frac{1}{8}$ scale may be too large, and a $\frac{1}{16}$ scale too small; a $\frac{1}{12}$ scale may be just right. If the draftsman has no $\frac{1}{12}$ scale (that is, a scale of 1 inch to the foot), he may make one by taking a piece of heavy drawing paper and cutting out a strip about the size of an ordinary scale, and laying off the inch divisions on it. Each division or part will represent 1 foot on the object. Divide one of the end parts into

12 equal parts, and each will represent 1 inch on the object. Lines indicating half- and quarter-inches may be drawn, if considered necessary.

Fig. 74 shows part of a scale made in this manner, giving

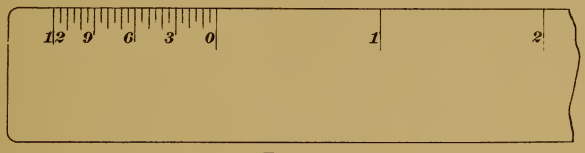


FIG. 74.

feet, inches, and half-inches—the quarters, eighths, etc. of an inch being judged by the eye.

DRAWING PLATE, TITLE: MACHINE DETAILS.

49. Fig. 1 shows a **double square-threaded screw** 3 inches in diameter and $1\frac{1}{2}$ inches pitch, having a hexagonal head and nut. The screw is $10\frac{1}{2}$ inches long, and the distance between the faces of the head and nut is $6\frac{3}{8}$ inches. The head and the nut are each $2\frac{15}{16}$ inches long, are hexagonal in shape, and their long diameters are $5\frac{1}{4}$ inches. Since this screw is drawn full size, and is comparatively of large diameter, the true projection of the helix is drawn instead of the conventional method used in Fig. 2 of the plate entitled Details.

Draw the center line $m\,n$; lay off $A\,3'$ equal to $6\frac{3}{8}$ inches, and through $3'$ draw CD perpendicular to $m\,n$. Make $3'E$ equal to $2\frac{15}{16}$ inches, and draw FG parallel to CD. Divide CD, which is $5\frac{1}{4}$ inches long, into four equal parts, and through the points C, H, J, and D, draw lines CL, HI, JK and DM parallel to $m\,n$. With $3'$ as a center, and $3'E$ as a radius, describe the arc IEK, intersecting HI and JK in I and K. Project the points I and K upon CL and DM, locating the points L and M, and pass through L and I and through K and M circular arcs tangent to FG. The centers of these arcs will lie on lines perpendicular to the center line $m\,n$, and midway between L and I, and between K and M. Therefore, draw NG parallel to the center line $m\,n$, through a point half the distance between JK and DM, and find by trial a point N at such a distance from G

that, with the radius $N G$, the arc will pass through K, G, and M. Draw the nut in the same manner. This is the conventional method of representing a nut.

To construct the screw, draw through some convenient point O a line $Q R$ parallel to $C D$. From O as a center, describe two semicircles whose diameters are equal to the top and bottom diameters of the screw thread, intersecting the line $Q R$ in the points Q, q, r, and R. From these points draw lines to S, s, T, and t, parallel to the center line $m n$; evidently these lines coincide with the top and bottom of the screw thread. The depth of the thread is found as in Fig. 2 of the plate entitled Details.

Divide the semicircles into any number of equal parts, in this case 6; this is best done by first dividing the exterior semicircle into the required number of parts, as Q, *1*, *2*, *3*, *4*, *5*, and R, and then drawing radii through each point from O, which divides the interior semicircle similarly. Lay off on the line $R t$, or any other line, as $U V$, which is parallel to the center line $m n$, the pitch of the screw, or $1\frac{1}{2}$ inches, and divide it into twice the number of equal parts that the semicircles have been divided into.

Now, construct the helix *6 5 4 3 2 1* W, as described in Plate V, for the top diameter; also the helix *6′ 5′ 4′ 3* X', having the same pitch, for the bottom diameter. As this is a double square-threaded screw, the widths, as well as the depths of the threads and grooves, are equal to $\frac{1}{4}$ of the pitch, or $1\frac{1}{2} \times \frac{1}{4} = \frac{3}{8}$ of an inch. (See Fig. 2, last plate.)

Consequently, to lay off the widths of the threads and grooves, divide the pitch, or line $U V$, into four equal parts, as *1*, *2*, *3*, and U, and through these points draw lines parallel to $C D$, intersecting the lines which represent the top and bottom diameters of the screw, in the points a, e, and Z'; b, g, and Z; c, f, and W; d, X, and Y; draw through these points other helical curves parallel to those already drawn. The remaining threads of the screw may be drawn in the same manner, but an easier and quicker method is to cut a curve of the same shape as those already drawn, out of a piece of bristol board or cardboard, and use it as a template. The manner of constructing

the curves $X\ 1'\ 2'\ 3'$ and $3\ 4'\ 5'\ 6'$ should be clearly evident from the drawing. The dotted curves need not be drawn by the student, as they are merely put in to show the connections between the different threads.

In Fig. 2 are shown a section and end view of a **shaft flange coupling,** used for connecting the ends of two shafts. In order not to take up too much room on the plate, the coupling is drawn to a reduced scale, which is marked on the drawing as 3 inches = 1 foot. Using the scale of 3 inches = 1 foot (see Art. **48**), draw the figure from the dimensions given, first drawing all of the sectional part, except the bolt. Then draw the end elevation as shown, and, lastly, the bolt in the sectional view. The part $A\ B\ C$ is a key sunk into the shafts to keep them from turning within the coupling. The shafts themselves are made of wrought iron, as indicated by the sectioning.

Fig. 3 is a front and side elevation of a **gland.** This is also drawn to a scale of 3 inches = 1 foot, and should be constructed without difficulty from the dimensions given. The line $O\ A$, marked $6\frac{3}{8}''\ r$, means that the radius of the arc $B\ A\ D$ is $6\frac{3}{8}$ inches long ; so, also, $C\ B$, marked $1\frac{1}{2}''\ r$, means that the radius of the arc $B\ E$ is $1\frac{1}{2}$ inches long. Since no dimensions are given for the other two arcs, it is understood that their radii are the same as for the first two. Whenever a dimension is given, like $O\ A$, specifying the length of a radius, the letter r, or the abbreviation *rad*, should always be placed after it.

Fig. 4 shows a **riveted joint,** or two plates riveted together. The front elevation and a cross-section through one of the rivets are given. The diameter of the rivets is $\frac{1}{2}$ inch, and the pitch (the distance between the centers of two consecutive rivets) is $1\frac{1}{2}$ inches. These, and the other dimensions, are obtained from the drawing. Draw the cross-section first, as shown in the figure, and, after that, the elevation. The scale is full size.

Fig. 5 shows a **clamp, dog,** or **carrier,** as it might be termed. It can be readily drawn from the dimensions given. It will be noticed that part of the pin $A\ B$ is flattened. This is seen more clearly in the top view, shown by the dotted lines. It is to be drawn to a scale of 3 inches = 1 foot.

Fig. 6 shows a **clamp box** to be attached to beams for

shafting to pass through. The scale to which it is drawn is half size, that is, 6 inches = 1 foot. The curves at *A*, *B*, etc. are not exact projections of the curve of intersection of the round and flat surfaces shown in the other view, but are drawn as circular arcs, from which they differ but little, and the time occupied in finding the different points on the curve is saved. This answers the purpose when making shop drawings, just as well as the exact method. The curve *CFD* is the projection of the part *DEF*, shown by the dotted lines in the elevation, which is removed in order that the nut may be turned around. *G* is an oil hole. It will be noticed that the bolt holes are larger than the bolts; this allows the clamp box a little play, should it be necessary. It also allows the holes to be cored in the box when the casting is made, instead of being drilled afterwards. On all drawings made for the shop, or on which dimensions are given or required, the scale should invariably be specified. If more than one scale is used, as in the last plate, where three different ones were used, it should be given for each figure.

DRAWING PLATE, TITLE: BAND-WHEEL.

50. This plate shows an elevation and cross-section of one-half of a **14-foot band-wheel** having eight arms. Draw both views at the same time, so that any part of the one view may be projected on to the other.

Draw in the principal center lines first, and then draw in the rim and hub in both views. With a 45° triangle draw in the center lines of the arms in the elevation, and draw in the arms in both views.

The cross-section shows that the wheel is crowned; that is, it is turned larger at the center and slopes gradually to the edges. This prevents the belt from slipping off, and accounts for the double line representing the periphery of the wheel in the elevation. The part of the arm sectioned at *A B* indicates that a cross-section on *A B* would look like the cross-section shown, and that the arms are elliptical in shape. This method of

showing the cross-section in cases of this kind is very commonly used in drawing rooms.

C D and *C′ D′* are key-ways for fastening the wheel to its shaft. The cross-sectional view shows that the hub is hollowed out. It was cored out thus when the wheel was cast, in order to save the time and expense of boring it through its whole length. This view, in connection with the dotted lines of the elevation, shows that the arms are hollow ; the cross-section on *A B* also shows it. The arms taper gradually from 7 inches at *F* to $5\frac{3}{8}$ inches at *G*, the same taper continuing on to *H*. The part *E F* has the same cross-section at every point, and, consequently, is straight. The core holes *I*, *K*, *L*, etc. are reinforced ; that is, they have bosses on the inside to strengthen the arms where the holes are. It is necessary that these holes be in every casting of this kind, so that the cores of the arms can be removed through them. The drawing can now be finished without further explanation.

DRAWING PLATE, TITLE: ECCENTRIC AND BRAKE LEVER.

51. Fig. 1 shows an elevation of an **eccentric and its strap.** The strap is made in two pieces, and bolted together with a small space $\frac{1}{32}$ of an inch wide between them. Locate the point *O*, the center of the strap, and draw the center lines, *A B*, *m n*, *C C′*, and *D D′*. Make the offset *O O′* one-half of the throw of the eccentric, or, in this case, $\frac{7}{8}$ inch, thus locating *O′*, the center of the eccentric shaft. Construct the rest of the view from the dimensions given, noting that the arc *E E′* and *F F′* are concentric with *O*, while *G G′* and *H H′* are concentric with *O′*. The part *F F′ G′ G* is entirely open, and is made so in order to lighten the eccentric.

Fig. 2 is a section of the **eccentric and strap.** The section is drawn in a conventional manner, it being all taken on the line *A B*, Fig. 1, except that part of the eccentric between *G′* and *F′*, where, instead of sectioning, the drawing shows it open from *L* to *P*, Fig. 2, as if the section had been taken on the line

O J. This attracts attention to the open part of the eccentric, and shows it more clearly.

It will be noticed that the slope of the threads in the sectional part is the same as for the left-handed screw. The thread, however, is right-handed, and the reason for showing it in this manner is that it is the bottom of the thread that is being looked at; that is, the section of a right-handed nut and the projection of the bottom of a right-handed screw are the same as the projection of the top of a left-handed screw. It will also be noticed that the sectional lines on the eccentric run in opposite directions to those on the strap. This is always done when two different pieces meet, and serves to indicate that they are separate pieces. Each piece should be sectioned entirely in the same direction, no matter if there is a break, as in the present case, between *L* and *P*. This shows that *A B C D E* is one piece. The dotted hole at *K*, Fig. 1, is an oil hole.

Fig. 3 shows a **brake lever** drawn to a scale of 3 inches = 1 foot. Owing to its length being too great to be shown entirely on the drawing to this scale, the handle is shown as if a piece had been broken out, the dimension line, 4 feet 7 inches, giving the distance between the two centers *O* and *O'*. The lever should be readily drawn from the dimensions given. To proportion it properly, where the size of the paper does not permit the whole of it to be drawn, proceed as follows: The length between the centers is 4 feet 7 inches = 55 inches. The width through *O'* is $2\frac{1}{4}$ inches, and through *O* 4 inches. Hence, $4'' - 2\frac{1}{4}'' = 1\frac{3}{4}''$; $1.75''$ = the taper in 55 inches. Measure off *O A* = say, 2 feet. The width at *A* may be found as follows: $\frac{1.75}{55}$ = taper in 1 inch. $\frac{1.75}{55} \times 24 = .76$ inch, nearly, the taper in 2 feet. $4'' - .76'' = 3.24'' = B C$, or the width at *A*. Now locate the point *O'*, and from it as a center describe a curve $2\frac{1}{4}$ inches in diameter. Draw lines tangent to this curve, and parallel to the edges between *A* and *O* already found.

It should be noticed that the center of the brake lever in the left-hand view is not situated at the joint where the two parts

come together, but coincides with the center of the handle, as it should do.

52. Fig. 75 shows the ordinary conventional method of representing a nut. The bottom of the thread is $1\frac{1}{2}$ inches in diameter, and is represented by the dotted circle; this shows that it is intended for a screw $1\frac{1}{2}$ inches in diameter. The height of the nut equals the diameter of the bolt or screw on which the thread is cut. The two views on the center line $m\,n$ should be drawn without difficulty. To draw the curves $e\,a$ and $a\,d$, project b and c at right angles to $t\,v$ in the points d, a, and e; pass arcs of circles through e and a, and through

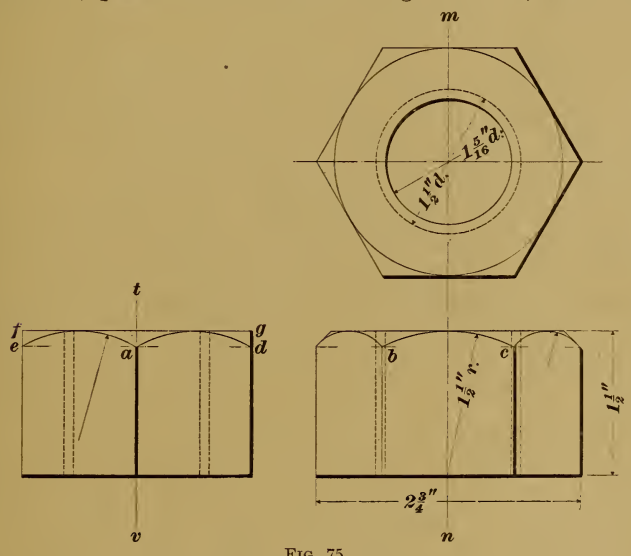


Fig. 75.

d and a tangent to $f\,g$, finding the centers of these arcs by trial. The best way of doing this is to draw lines parallel to $t\,v$ midway between e and a and between a and d. Then, by trial with the compasses, find a center on these lines such that an arc struck with the compasses from this center will pass through e and a (or a and d) and be tangent to $f\,g$. In the right-hand view, the radius of the arc $b\,c$ is the same as the height of the nut; the centers of the other two arcs are found by trial in the manner just described.

DRAWING PLATE, TITLE: ENGINEERING DETAILS.

53. Fig. 1 shows a top view and elevation in partial section of a **connecting-rod.** Draw the center lines $m\,n$ and $m'\,n'$; lay off on one of them the length of the rod between the centers (4 feet $3\frac{1}{2}$ inches), and through the two points just located draw the vertical center lines $t\,v$ and $t'\,v'$. The two views should be easily drawn from the dimensions given. It will be noticed by the sectioning that the boxes are made of brass, lined with babbitt metal. The bolt in the crank end of the rod is marked, "Taper of Pin $\frac{1}{16}$ of an inch per foot." To draw it, locate its center line, and lay off under the head its diameter, 2 inches. Measure off on the center line from the head downwards 12 inches, and lay off at this point a line representing a diameter of $1\frac{5}{16}$ inches. Join by straight lines the ends of the two lines just drawn, and they will form the edges of the pin.

Fig. 2 shows an **expansion-joint.** It is placed near the middle of a long line of steam pipes to allow for the expansion and contraction of the pipes, owing to the great changes of temperature. A is the gland for the stuffing-box C, which forms part of the body B, to which it is fastened by studs not shown in the drawing, but which pass through holes in the flanges of A and B. Packing is placed in the stuffing-box, making a steam-tight arrangement. The sliding tube marked D is made of cast iron, partly covered with a thin cylinder of brass called a **sleeve.** The gland A and that part of B through which D passes are lined, or **bushed,** with brass. This is done to keep the surfaces that slide over each other from rusting by the action of the steam and sticking together, as would be the case if they were iron. The tube D is bolted to one section of the pipe, the other section of the pipe being bolted to the other end of the body B. The rods E, E act merely as guides. When the whole is in position, the two nuts at F, F will not touch the flange, but will be at a little distance from it; the gland of the stuffing-box will also be about half-way in. When the pipe is heated it expands, and the two ends at D and B tend to come together; the brass part D slides through its stuffing-box;

the distance between the end H and the edge G decreases, and the distance between the nuts F and the flange increases. When the pipe is cooled it contracts; the distance between H and G increases, and between the nuts F and the flange it decreases. The student should be able to draw the figure from the dimensions given.

DRAWING PLATE, TITLE: REVERSING LEVER.

54. This plate shows a drawing of a **reversing lever,** together with its stand, which is suitable for a brake lever on hoisting engines. To draw it, first draw the center line $m\,n$, the base line $A\,B$, and the base and bosses in the side elevation. Locate the center O on $m\,n$, 9 inches below $A\,B$. With O as a center, and a radius equal to 2 feet 3 inches, describe an arc of a circle. On each side of $m\,n$ lay off 12 inches, and draw vertical lines through the points; these lines intersect the arc just described in O', O', the centers of the pins. The arc intersects $m\,n$ in P; hence, lay off 1 inch on each side of P, along $m\,n$, and draw arcs of circles through these points; they will be the limiting lines of the top and bottom of the wrought-iron sector. With the two centers O' and a radius of 1 inch, describe the two circles as shown. Set the spacing dividers to 1 inch, and step off the teeth on the outer circular arc. Draw all the short shaded lines, as $a\,b$, radial; that is, if a line be drawn from the point a to the center O, the point b will fall on this line. Measure, from the base line upwards, $C\,D = 7\frac{1}{8}$ inches and, with a center on $m\,n$ and a radius equal to 10 inches, pass an arc through the point D; also one through E, half an inch below D, using the same center. With a radius equal to 18 inches, find by trial the center Q, which is so located that an arc described with this point as a center, with a radius 18 inches long, will be tangent to the arc just passed through D, and to the circle described about O'. With the same center, and a radius $\frac{1}{2}$ of an inch longer, describe the other arc tangent to the arc through E. Now draw a faint pencil line on each side of, and parallel to, $m\,n$, and distant $5\frac{3}{4}$ inches from it. With R as a center, and a 3-inch radius, describe an arc tangent

to the perpendicular just drawn, and to the upper edge of the base. Find by trial the center Q', such that an arc described with Q' as a center, and a radius equal to $19\frac{3}{8} + \frac{1}{2} = 19\frac{7}{8}$ inches, will be tangent to the arc just drawn and to the circle whose center is O'. With the same center, and a radius equal to $19\frac{3}{8}$ inches, describe another arc tangent to an arc described with R as a center and a radius equal to $3\frac{1}{2}$ inches. The construction is the same for each side of $m\ n$.

The remainder of this view can be easily drawn from the dimensions given. The dotted part between C and O is a rib; it is shown more clearly in the front elevation, in which $F\ G$ is its outer edge. The line $c\ d\ e$ on the top of the lever indicates a flat surface. In the front elevation the line $H\ I$ represents the line described with the $19\frac{3}{8}$-inch and $3\frac{1}{2}$-inch radii, and the line $H'\ I'$ represents the line described with the 18-inch and 10-inch radii. Theoretically, the entire rib $F\ G\ K\ L$ should be sectioned, and the outline of the sectional part between N' and N should be dotted, but, for convenience, a conventional method is used. The thickness, $\frac{3}{4}$ inch, of the sectional part, is the thickness of all that part of the arm below the base, except that included between the dotted lines on the side elevation. The dotted line $R\ S$ is the projection of the edge $R'\ S'$.

DRAWING PLATE, TITLE: 5-INCH GLOBE VALVE.

55. On this plate is shown a longitudinal section of a **5-inch globe valve.** Draw the center lines $m\ n$ and $p\ q$. Draw the faces of the flanges $A\ A'$ and $B\ B'$, $7\frac{5}{8}$ inches from the center line $m\ n$, and construct the flanges according to the dimensions given. Locate P on $m\ n$ 6 inches below $p\ q$, and with a center on $m\ n$, and a radius of $6\frac{1}{2} + \frac{5}{8} = 7\frac{1}{8}$ inches, describe the arc $C\ P\ C$. With the same center, and a radius $6\frac{1}{2}$ inches long, describe the arc $C'\ C'$. With a center on the inside edge $E\ E'$ of the flange, and a radius equal to 2 inches, describe the arc $C\ D$ tangent to $C\ C$. With the same center, describe the arc $C'\ D'$ tangent to $C'\ C'$, and draw $D'\ D''$ straight. With a radius equal to $\frac{1}{4}$ of an inch, describe the fillet $D\ E$, tangent to $D\ C$ and $E\ E'$. $F\ F$ and $F''\ F''$ are both struck with

the same radius as CPC, and no difficulty should be experienced in drawing the upper part of the body.

The valve is made of brass, as shown by the method of sectioning. The seat H is flat, in order to obtain a better fit, and save time in grinding; it makes an angle of 45° with pq. The lower end of the valve stem, used to raise the valve by turning the hand-wheel on the upper end, is curved to a radius of $4\frac{1}{16}$ inches, having a center O.

The lower edge of the sectioned part of the valve is struck with a radius having the same center. The screw is a single square thread, having 3 threads per inch, and the nut is square. It is made of brass, and inserted through a hole cored in the boss on the bottom of the upper casting or bonnet. The screw is then screwed in, and the hand-wheel put on the upper end, which is made square. The bonnet is then placed upon the body of the valve, and bolted down, as shown. There is also a stuffing-box in the bonnet, as shown, to prevent leakage. It will be noticed that the section of the hand-wheel is in all respects similar to the one shown in the plate entitled Details.

DRAWING PLATE, TITLE: SHAFT HANGER.

56. This plate shows a drawing of a **hanger** used to support shafting. There are shown a side view, half in elevation and half in section on the line YZ, part of a top view, part of a bottom view, a complete longitudinal section on the center line mn at right angles to the plane of the paper, and two small sections through the frame. For convenience in describing, the different views will be numbered.

Draw Fig. 1 first, which shows a half elevation and a half section. No great difficulty should be experienced in drawing it. It will be noticed that the journal-box through which the shaft passes has a spherical bearing; this is shown by the fact that the radius of the curve is the same, or $1\frac{1}{2}$ inches, in Fig. 1 and Fig. 2, the latter being a view at right angles to Fig. 1. The object to be attained by making the bearing partly spherical is to provide for self-adjustment in any direction, in case the shaft is not perfectly straight.

Fig. 2 shows very plainly how the shaft may be adjusted vertically. The set-screws A, A are released, and the large screws B and B' are screwed up or down, according as the shaft is to be raised or lowered, the spherical bearing allowing of adjustment at every point. The set-screws are then screwed down or set, so as to prevent B and B' from changing their positions. It will be noticed that the journal-box is made in two parts. Fig. 2 is a section on a line $m\,n$, and shows the whole length of the hanger. The part sectioned at E and E is shown in Figs. 1 and 4 by $E\,E$. The dotted lines between them show the projection of the boss drawn at F, in Figs. 1 and 4, but not seen in this view. The lines forming the outline $E\,D\,E'\,E$ show the projections of the hanger frame. The screws B and B' are made hollow, to lighten them. The dotted ellipse in B is the projection of the rib shown at L in Fig. 1.

Fig. 3 is a bottom view as far as the line $C\,C$, after the oil pan and screw B' have been removed. D is the projection of the boss D in Figs. 1 and 2, through which the set-screw A passes.

Fig. 4 is a partial top view. This can be drawn from the dimensions given, without any special instructions.

Fig. 5 is a section through $C\,D$, Fig. 1, and $G\,H$, Fig. 2. It shows the shape of the frame, which is also shown by the dotted outline P, in Fig. 4. This section is drawn more particularly to show that the radius of the curve on each side of any section of the vertical part of the frame is the same.

Fig. 6 is a section through $A\,B$, Fig. 4, and $I\,K$, Fig. 1.

DRAWING PLATE, TITLE: BENCH VISE.

57. This plate shows a **bench vise and its details.** A drawing of this kind is called a **detail drawing.** Fig. 1 is a complete top view, and Fig. 2 is a section through the center line $C\,D$. The remaining figures are drawings of the different parts, or details. The actual practice in the drawing-room would be to draw Figs. 1 and 2 first, and then the details, but in the present case the student will do well to draw the details first, as it will help him in drawing the other two views.

particularly since nearly all of the dimensions are given on the details. Following out this plan, leave space for Figs. 1 and 2, and begin by drawing Fig. 3. This consists of three views of the jaw, the part marked *A* in Figs. 1 and 2. The parts marked *B*, *C*, and *D*, in Figs. 1, 2, and 3, are circular in shape, so as to permit the back jaw *A* of the vise to swing when the pin *E* is removed. This allows the vise to hold tapered pieces with as much firmness as straight ones.

Fig. 4 is a detail, with dimensions, of the pin *E*.

Fig. 5 is a detail of that part of the vise marked *F* in Figs. 1 and 2, and also of the wrought-iron nut *G*. The reason that only a part of the nut *G* is sectioned in Fig. 2 is that a conventional method has been used. In reality, the whole of the nut should be sectioned. It would be impossible to take a section of the nut in the manner shown.

Figs. 6 shows a top view, longitudinal section, and cross-section of the front jaw. This is cored out to admit the screw and the nut. The form of the cored part is shown by the longitudinal section and cross-section through *E F* and *A B*. The front jaw moves in and out with the screw, as shown by Fig. 2, the collar *L* being held in place by the small set-screw. This is sufficient, since there is no stress on the collar beyond the force required to pull the jaw outwards, the force exerted by screwing the jaws together coming entirely on the surface *M* of the screw head.

A separate detail drawing of the screw is not required, since all the dimensions are given in Fig. 2. Figs. 1 and 2 can now be drawn, the necessary dimensions being obtained from the details.

For ordinary shop drawings, the details are usually drawn to a larger scale than the general drawings, Figs. 1 and 2. In this case the size of the plate would not permit an enlargement.

DRAWING PLATE, TITLE: PROFILES OF GEAR-TEETH.

58. If a circle be rolled on a straight line without sliding, a point on the circumference of the circle will describe a curve called the **cycloid**. The circle is called the **generating**

circle. The shape of the curve and the manner of drawing it are shown in Fig. 1. Let *O* be the center of the generating circle, which is $1\frac{3}{4}$ inches in diameter, *P* the point on the circumference of the generating circle, and *A B* the straight line on which the generating circle is rolled, and which is equal in length to the circumference of the generating circle, or $1\frac{3}{4}'' \times 3.1416 = 5.4978$, say $5\frac{1}{2}$ inches. The generating circle should be so placed that its center *O* lies over the center of the line *A B*, as shown. Divide the generating circle into any number of equal parts, in this case 12, or *P 1*, *1-2*, *2-3*, *3-4*, etc., and through these points draw lines *C D*, *E F*, *G H*, etc. parallel to the line *A B*. Through the center *O* of the generating circle draw the radius *O 6*. Divide each half of the line *A B* into half the number of equal parts that the generating circle is divided into, as *A 1*, *1-2*, *2-3*, etc., and through these points draw lines perpendicular to *A B*, terminating in the line *G H*, as *A G*, *1-1'*, *2-2'*, *3-3'*, etc. From the point *1'*, with a radius equal to the radius of the generating circle, as *O 6* or *1'-1*, describe an arc intersecting the line *K L* in the point P^1; from the point *2'*, with the same radius, intersect the line *I J* in the point P^2; from the point *3'*, with the same radius, intersect the line *G H*; continue in a similar manner with the remaining points *4'*, *5'*, *7'*, *8'*, etc., intersecting the lines *E F* and *C D* in the points P^4, P^5, P^7, P^8, etc. The points *A*, P^1, P^2, P^3, etc. are points in the curve through which the cycloid may be drawn. It will be noticed that when the center *O* of the generating circle coincides with the point *G*, the point *P* on the circumference of the generating circle coincides with the point *A*; and that when the generating circle is revolved towards the right, without sliding, until the center *O* coincides with the point *1'*, the point *P* will coincide with the point P^1. Thus it is seen how the point *P* passes through all the points from *A* to *B*, namely, *A*, P^1, P^2, P^3, etc., when started at *A* and revolved towards the right to *B*.

59. If the generating circle be rolled, without sliding, on the outside of the circumference of an arc of a circle supposed to be at rest, instead of being rolled on a straight line, the curve

described by a point P of the generating circle will be an **epicycloid.**

The manner of drawing such a curve is shown in Fig. 2. $A\,B$ is the arc upon which the generating circle is rolled, its center being at S, and its radius being $3\frac{1}{2}$ inches. The diameter of the generating circle is in this case the same as in Fig. 1, or $1\frac{3}{4}$ inches. Make the lengths of the arcs $6\,A$ and $6\,B$ equal to half the length of the circumference of the generating circle, by first calculating the length of half the circumference of the generating circle, and drawing a straight line tangent to the arc $A\,6\,B$ at 6, and making it equal in length to half the circumference of the generating circle. Then make the arc $6\,A$ equal to this line by means of the approximate method given in problem 20, Art. **33.** Divide the arc $A\,6\,B$ and also the generating circle into the same number of equal parts, in this case 12, as $A\,1$, 1-2, 2-3, etc., and $P\,1$, 1-2, 2-3, etc., and draw radii from the center S to the points of division on the arc $A\,6\,B$. During the revolution of the generating circle, the center O will describe an arc $m\,O\,n$ concentric with the arc $A\,6\,B$, and having the same number of degrees in it as $A\,6\,B$. Produce the radii just drawn to the arc of center positions $m\,O\,n$, intersecting this arc in the points m, $1'$, $2'$, $3'$, $4'$, etc. Through the points of equal divisions, 1, 2, 3, etc., of the generating circle, pass concentric arcs having the center S, as $C\,D$, $E\,F$, $G\,H$, $I\,J$, and $K\,L$. With the points $1'$, $2'$, $3'$, $4'$, etc. as centers, and radii equal to the radius of the generating circle, describe arcs cutting the arcs $K\,L$, $I\,J$, $G\,H$, etc., in the points P^1, P^2, P^3, etc., which are points on the epicycloid.

60. When the generating circle rolls on the inside of the arc, the curve described by a point on the circumference is called a **hypocycloid.** The method of drawing it is similar in all respects to that just given for the epicycloid. The student should be able to construct it from the drawing without further explanation. The diameter of the generating circle is $1\frac{3}{4}$ inches, as before.

61. Suppose that a string is wound upon a cylinder, and that the end of the string is at the point P, in Fig. 3. If this

string be unwound from the cylinder, keeping it constantly tight, the end P will describe a curve known as the **involute of the circle,** or, more simply, the **involute.** To construct it geometrically, let O be the center of the given circle representing the cylinder, which, in Fig. 3, is $2\frac{1}{2}$ inches in diameter, and P the free end of the string when wound upon the cylinder. Divide one-half of the given circle representing the cylinder into any number of equal parts, in this case 6, as *P 1*, *1-2*, *2-3*, etc., and through each of these points draw tangents to the circle, as P^1, P^2, P^3, etc. To draw these tangents, first draw the radii *O 1*, *O 2*, *O 3*, etc., and then draw the tangents *1* P^1, *2* P^2, *3* P^3, etc. at right angles to them. By means of the approximate method given in problem 21, Art. **33,** find the length of the arc *1 P*, and make the length of the tangent *1* P^1 equal to this length ; of the tangent *2* P^2, equal to twice this length ; of the tangent *3* P^3, equal to three times this length, and so on. The curve drawn through the points P^1, P^2, P^3, P^4, etc. will be the required involute. The use of these curves will now be explained :

62. On the plate entitled Spur Gear-Wheels, Fig. 1, is shown one-half of two **spur gear-wheels** in mesh. The two dotted circles tangent to each other at P are concentric to the centers of the gear-wheels, and are called the **pitch circles.** The diameter of any gear-wheel is always understood to be the diameter of its pitch circle unless it is specified as **diameter at root,** or **diameter over all.** The length of that part of the pitch circle between the centers of any two consecutive teeth is called the **circular pitch,** or simply the **pitch.** Thus, in the last-mentioned figure, the length of the arc $a\,b$ is equal to the pitch of either gear-wheel. When the gear-wheels are cut in a gear-cutter, the width of the tooth $c\,d$ on the pitch line is equal to the space $d\,f$; that is, the arc $c\,d$ is equal to the arc $d\,f$, and each is equal to half the pitch. When the gear-wheels are cast, that is, when they are not cut in a gear-cutter, clearance is given between the back of one tooth and the front of the tooth following, to allow for inequalities in casting. This clearance, or **back lash,** as it is usually termed, is generally

made equal to 4% of the pitch. This is done by making the thickness of the teeth $c\,d$ equal to .48 of the pitch.

The part $C\,C_1$ of the tooth which lies beyond the pitch circle is called the **addendum,** and the part $C\,C_2$ which lies below it is called the **root.** The **face** of the tooth is the part $C\,C_1\,C'\,C$, Fig. 2, of the tooth above the pitch circle, extending the whole width of the tooth. The **flank** is the part $C\,C_2\,C''\,C$, Fig. 2, of the tooth below the pitch circle, extending the whole width of the tooth. The terms addendum and root mean distances only, while face and flank mean surfaces.

The usual practice is to make the addendum equal to $.3\,P$, and the root equal to $.4\,P$. $P =$ the circular pitch. The distance $C_1\,C_2$ is called the whole depth of the tooth. The method of describing the curves of teeth shown on the plate entitled Profiles of Gear-Teeth, Fig. 4, is a convenient way of drawing the **cycloidal,** or **double-curved teeth.** Cycloidal teeth are constructed by making the outline of the face a part of an epicycloid, and the flanks a part of the hypocycloid; hence the name—double-curved teeth.

63. In Fig. 4 of the plate entitled Profiles of Gear-Teeth, let $A\,B$ be part of a pitch circle struck with a radius of, say, $5\frac{1}{2}$ inches. For convenience in drawing the tooth, let the pitch be 2 inches. With O as a center, which is the center of the gear-wheel, and a radius equal to $5\frac{1}{2}$ inches, describe the arc $A\,B$, part of the pitch circle. Through O draw a straight line $O\,S$, cutting $A\,B$ in P. Take the radius of the generating circles $S\,P$ and $S'\,P$, equal to $1\frac{7}{8}$ inches for this case, and describe arcs having centers at S and S' on the line $O\,S$. With O as center and $O\,S$ as radius, describe the arc $S_2\,S_1$. In connection with gear-wheel teeth, the generating circles are frequently called **describing circles.** Roll the outer describing circle upon $A\,B$ in such a manner that the center S will move in the direction of the arrow along the arc $S_2\,S_1$. By means of the method given in Fig. 2, find the points P^1, P^2, P^3, etc. on the epicycloid described by the point P. Trace a faint curve through the points just found, and measure off on the pitch circle the thickness of the tooth.

$$P\,D = .48\,p = .48 \times 2'' = .96''.$$

Make $E\,F =$ the addendum $= .3 \times p = .3 \times 2'' = .6''$.

With O as a center and $O\,F$ as a radius, describe an arc cutting the epicycloid in G. Now roll the inner describing circle on $A\,B$, so that its center S' moves in the direction of the arrow, and find the points P_1, P_2, P_3, etc. of the hypocycloid described by the point P, through which trace a faint curve. Make $E\,F'$ equal the flank of the tooth $= .4\,p = .4 \times 2'' = .8''$, and with O as a center and $O\,F'$ as a radius, describe an arc cutting the hypocycloid in G'. $P\,G'$ is the outline of the flank of the tooth, and $P\,G$ that of the face. Since it would be a tedious operation to draw all the tooth curves in this manner, it is usual to approximate the curves by means of circular arcs; that is, to find, by trial, a center Q, and a radius $Q\,P$, such that an arc described from this center, and with this radius, will pass through the points on the curve $G\,P$, and coincide with that curve as closely as possible; also, to do the same with regard to the curve $P\,G'$, using the center Q' and the radius $Q'\,P$. To find the center Q or Q' of these circular arcs proceed as follows: With P and G as centers and any radius, describe arcs intersecting in C and C'. Draw a straight line through C and C'; the center Q must line on $C\,C'$ to the left of $G\,P$. Try different points *1*, *2*, *3*, *4*, etc. on this line as centers, and *1* G, *2* G, etc. as radii, and see if one of the arcs struck with either one of these centers and radii will coincide with the epicycloidal curve $G\,P$. Make this circular arc fit the curve for a short distance beyond G—as far as P^3, for example; this will ensure the arc being more nearly correct. This should be done in every case when finding an approximate radius of this kind. Continue in this manner until the point Q is found, such that an arc struck with Q as a center and $Q\,G$ or $Q\,P$ as a radius will coincide as closely as possible with $G\,P$. If a circle were drawn with O as a center and $O\,Q$ as a radius, the centers of all the circular arcs of the faces of the teeth would lie in this circle, and the radii of these arcs would be equal in length to $Q\,P$. Hence, to find the center Q_1 of the arc $D\,H$ forming the back of the tooth, take D as a center and $Q\,P$ as a radius, and describe a short arc cutting, in Q_1, the circle passing through Q. Then, with Q_1 as a center and the same radius, describe the arc $D\,H$. In a similar manner, find the center Q' and describe $P\,G'$, also

$D\,H'$. Instead of letting the flank form a sharp corner at the bottom of the tooth, as shown dotted at G', it is usual to put a small fillet there, as shown by the full line. This makes the tooth stronger and less liable to break or to crack in casting. The entire tooth outline or curve $G\,P\,G'$ or $H\,D\,H'$ is called the **profile** of the tooth.

64. A **rack** is a gear-wheel whose pitch circle is a *straight line;* the tops of the teeth all lie in the same plane. A portion of a rack and one tooth are shown in Fig. 5. Take the pitch the same as before, then the addendum and root are also the same, that is, .6 of an inch and .8 of an inch. Take the radius of the describing circles $1\frac{7}{8}$ inches, as before. It is evident that the tooth profile will be formed of parts of cycloids, formed by rolling the describing (generating) circle upon the pitch line $A\,B$. Draw a small part of the cycloidal curves, as shown in the figure, by the method given in Fig. 1 ; lay off the addendum and root, and find the approximate radius in the same manner as in the last figure. The centers of the curves for the faces and flanks of all the teeth of the rack will evidently line on the straight lines passing through Q and Q', respectively, and parallel to the pitch line $A\,B$.

65. In Fig. 6 is shown the manner of drawing the **involute,** or **single-curve tooth.** The profile in this case is formed of a portion of an involute curve and a portion of the radius of the pitch circle. The circle from which the involute is constructed is called, in this case, the **base circle.** To find it, draw the pitch circle, of which the arc $A\,B$ is a part, with a radius equal to $5\frac{1}{2}$ inches, and having its center at O. Draw any radius, $O\,W$, cutting the arc $A\,B$ in D. Through D draw the straight line $E\,F$, making an angle of 75° with $O\,W$. With O as a center and a radius to be found by trial, draw a circle tangent to $E\,F$. This circle, of which the arc $H\,G$ is a part, is the base circle, and cuts $O\,W$ in P. Upon this circle construct, in exactly the same manner as was shown in Fig. 3, a portion of an involute curve, passing through P. Lay off the addendum $I\,K = .6$ of an inch, and, with O as a center and $O\,I$ as a radius,

describe an arc to form the top of the tooth, intersecting the involute in L. That part of the flank below the base circle is straight, and is a part of the radius drawn to the point P. $K I'$ is the root. The tooth has a fillet at L' and R', as in cycloidal teeth. A circular arc is passed through the points L and P, coinciding as nearly as possible with the involute curve $L P$. Its center Q is found in the same manner as in Fig. 4. For involute teeth it is only necessary to find the one center Q; the centers for all the remaining teeth lie on a circle having O as a center, and passing through Q. To draw the other side of the tooth, lay off on the pitch circle $M N = .96$ inch, as before. With M as a center and $Q N = Q P$ as a radius, draw an arc cutting, at Q_1, the circle passing through Q; with Q_1 as a center, and the same radius, describe the part $P' R$ of the tooth profile above the base circle. The part $P' R'$ below the base circle is a part of the radius $O P'$.

In drawing any of the curves previously described, the greater the number of parts into which the describing or base circles are divided the greater will be the accuracy obtained. The profile of the rack tooth used for involute gears is a straight line making an angle of 15° with a line drawn perpendicular to the pitch line. Its construction is shown in Fig. 7.

DEFINITIONS AND CALCULATIONS.

66. When a revolving shaft transmits motion to another shaft parallel to it by means of gear- or tooth-wheels, in such a manner that two corresponding points, one on each gear-wheel, always lie in the same plane, the two gears are called **spur gear-wheels.** When the shafts are not parallel, but their axes intersect in a point, as O in the plate entitled Bevel Gears, they are called **bevel gear-wheels.** If two bevel gear-wheels which work together have pitch diameters of the same size, they are called **miter gear-wheels.** From what has preceded, it is evident that *the circular pitch multiplied by the number of teeth equals the circumference of the pitch circle.*

Let p = circular pitch of gear-wheel ;
n = number of teeth ;
d = pitch diameter ;
π = 3.1416 (π is pronounced **pi**).

Then, $$d = \frac{p\,n}{\pi}, \qquad (1.)$$

or, *the diameter of the pitch circle equals the circular pitch multiplied by the number of teeth divided by 3.1416.*

$$p = \frac{d\,\pi}{n}, \qquad (2.)$$

or, *the circular pitch equals the pitch diameter multiplied by 3.1416 divided by the number of teeth.*

$$n = \frac{d\,\pi}{p}, \qquad (3.)$$

or, *the number of teeth equals the pitch diameter multiplied by 3.1416 divided by the circular pitch.*

When constructing cycloidal teeth for gear-wheels, the diameters of the describing circles are usually made equal to one-half the diameter of the pitch circle of a gear-wheel having 12 teeth, of the same pitch as those of the gear-wheel about to be made.

Let d' be the diameter of the describing circle ; then,

$$d' = \frac{12\,p}{\pi} \times \tfrac{1}{2}, \text{ or } d' = \frac{6\,p}{\pi}. \qquad (4.)$$

Addendum = $.3\,p$; root = $.4\,p$; thickness of teeth for cast gears = $.48\,p$, and for cut gears $\frac{1}{2}\,p$.

DRAWING PLATE, TITLE: SPUR GEAR-WHEELS.

67. This plate shows the halves of two cast **gear-wheels**, having cycloidal teeth, which work together, a cross-section of each gear being also given. The drawing is full size, the wheels not being shown entire for want of room ; to have done so it would have been necessary to make the drawing to a reduced scale. The pitch is 1 inch, the number of teeth in the large

gear is 36, and in the small one 18. The pitch diameter of the large wheel is found by formula **1** to be

$$d = \frac{1 \times 36}{3.1416} = 11.46 \text{ inches, nearly.}$$

The pitch diameter of the small gear $= \frac{1 \times 18}{3.1416} = 5.73$ inches, nearly.

The diameter of the describing circle is found by formula **4** to be $d' = \frac{6 \times 1}{3.1416} = 1.91$ inches.

For all practical purposes, the diameter of the describing circle may be taken to the nearest 16th of an inch. For circular pitches under $\frac{1}{2}$ inch, approximate the diameter of the describing circle to the nearest 32d of an inch. To find the nearest 16th or 32d, multiply the decimal part of the diameter by 16 or 32, and take the nearest whole number of the product as the number of 16ths or 32ds that the decimal represents. Thus, in the above, the decimal part of the diameter is .91 inch ; $.91 \times 16 = 14.56$. The nearest whole number to 14.56 is 15 ; hence, the diameter of the describing circle is $1\frac{15}{16}$ inches. If the diameter had been required to the nearest 32d, $.91 \times 32 = 29.12$; 29 is the nearest whole number ; hence, the diameter would be $1\frac{29}{32}$ inches. In this case, take the diameter as $1\frac{15}{16}$ inches, approximating to the nearest 16th for all circular pitches above $\frac{1}{2}$ of an inch. The addendum will be $.3 \times 1$ inch $= .3$ of an inch, the root $= .4 \times 1$ inch $= .4$ of an inch, and the thickness of the tooth on the pitch circle $= .48 \times 1$ inch $= .48$ of an inch.

Draw the line of centers $O\,O'$ between the two axes. With O as a center describe a semicircle having a diameter of 11.46 inches, cutting $O\,O'$ in P. With O' as a center, describe a semicircle having a diameter of 5.73 inches which shall be tangent to the first circle ; this semicircle also cuts $O\,O'$ in P. These are the pitch circles. Divide the larger pitch circle into $\frac{36}{2}$, or 18 equal parts, by using the protractor. This is accomplished by laying the protractor on the drawing in such a manner that the center of the protractor coincides with the center O of the gear-wheel,

and then laying off on the drawing 18 divisions, each equal to 10 degrees. The reason for this will be clear when it is remembered that there are 360° in a circle, or $\frac{360°}{2} = 180°$ in a semicircle, and as there are 18 teeth in the semicircle, $180° \div 18 = 10°$, which is the angle between two lines drawn from the centers of any two consecutive teeth to the center O. In a like manner, any circle may be divided into parts by using the protractor. Make $C C_1 = .3$ inch = addendum, and $C C_2 = .4$ inch = root. With O as a center, and $O C_1$ and $O C_2$ as radii, describe light circles, called **addendum** and **root circles,** to represent the tops and bottoms of the teeth. Consider the points of division just laid off on the pitch circle as the centers of the teeth, and lay off on each side one-half of the thickness $c d$ of the tooth, or $.48 \times \frac{1}{2} = .24$ inch. Upon another sheet of paper, strike a short arc of the pitch circle, and construct the profile of the tooth as described in the plate entitled Profiles of Gear-Teeth, using describing circles $1\frac{5}{16}$ inches in diameter. Having found the centers Q and Q_1 of the circular arcs used for the profiles of the teeth, draw circular arcs through these centers, as previously described; then, with O (see plate entitled Spur Gear-Wheels) as a center, and the same radii, describe circles; these circles will contain the centers of the circular arcs which form the teeth profiles. With the point A as a center, and a radius equal to the radius of the face of the tooth (found on the other sheet of paper before mentioned), describe an arc intersecting the circle of face centers at Q. With Q as a center, and the same radius, describe the arc $A D$ for the face of the tooth, the point D being the point of intersection of $A D$ with the addendum circle. In the same way, draw the remaining faces of the teeth. To draw the flanks, take a point representing the intersection of a tooth profile with the pitch circle (the point B, for example) as a center, and a radius equal to the radius of the flank found on the other paper on which the tooth profile was drawn, and describe an arc intersecting the circle of the flank centers in Q_1. With Q_1 as a center, and the same radius, describe the flank curve, stopping at the root circle. Draw the flanks of the remaining teeth in the same way, and then put in

the fillets. The remaining part of Fig. 1 can be easily drawn from the dimensions given.

Fig. 2 is a conventional method of drawing cross-sections of gears. The hubs and rims are sectioned, but the teeth and arms are not. This is similar to the wheel shown on the plate entitled Details. This method of sectioning makes the views clearer, and saves the time spent in sectioning.

In Fig. 3 the entire gear is sectioned except the teeth. The student should now be able to finish the plate without further instructions.

DRAWING PLATE, TITLE: BEVEL-GEARS.

68. To draw in section and projection two cast **bevel-gears** whose axes intersect at right angles: The number of teeth in the large gear is 20; in the pinion 16. The circular pitch is 1 inch; the teeth are to be of the cycloidal form, having a face 2 inches wide. In any kind of gearing, whether spur, bevel, or spiral, the smaller wheel is called the **pinion.**

Calculate the pitch diameters, addenda, roots, and describing circles by the same rules that were given for spur-gears.

$$\text{Diameter of pinion} = \frac{16 \times 1 \text{ inch}}{3.1416} = 5.09''.$$

$$\text{Diameter of the large gear} = \frac{20 \times 1 \text{ inch}}{3.1416} = 6.37''.$$

$$\text{Diameter of describing circle} = \frac{6 \times 1 \text{ inch}}{3.1416} = 1.91''.$$

Take this as $1\frac{5}{16}$ inches, as in the last plate.

Addendum = .3 inch; root = .4 inch. The sectional view must be drawn first. Draw PP' and through some point P' on this line draw $P'P_1$ perpendicular to it. Lay off PP' equal to the diameter of the pinion = 5.09 inches; also $P'P_1$ equal to the diameter of large gear = 6.37 inches. Bisect PP' and $P'P_1$, and draw OM and ON perpendicular to those lines at the point of bisection; they intersect in O. OM and ON are the axes of the two gears, and intersect at right angles

as required. Draw $P\,O\,P_1$ and $P'\,O$. Through P draw $A\,P\,M$ perpendicular to $O\,P$. Through P' draw $M\,P'\,N$ perpendicular to $O\,P'$, and through P_1 draw $P_1\,N$ perpendicular to $O\,P_1$. $P\,M$ and $P'\,M$ intersect at M, on the line $O\,M$; $P'\,N$ and $P_1\,N$ intersect at N, on the line $O\,N$. Lay off $P'\,C'$, $P\,C$, and $P_1\,C_1$, each equal to 2 inches, or the width of the face of the teeth; these lines are called the **pitch lines**, and the width of the face of the teeth is always measured on these lines. Lay off $P\,A$ equal to .3 inch = the addendum, and $P\,B$ equal to .4 inch = the root. Lay off $P'\,E$ and $P'\,D$ for the addendum and root of the other side, and $P'\,E'$ and $P'\,D_1$ for the addendum and root of the large gear. All of these addenda and roots are each equal to .3 inch and .4 inch, respectively. In bevel-gears, all straight lines of the tooth profiles pass through the point of intersection O of the axes; hence, draw $A\,O$, and $A\,A'$ will be the projection of the top of the tooth. Draw $B\,O$, and $B\,B'$ will represent the bottom of the tooth, the line $A'\,C\,B'$ being perpendicular to $O\,P$. Make $B\,F'$, $D\,F$, $D_1\,F_1$, etc. each equal to $\frac{1}{2}$ inch, according to dimensions. Join F', F, F_1, and F_2 with O, intersecting the perpendiculars through C, C', and C_1 (namely, the lines $A'\,C\,B'$, etc. produced) at G', G, G_1, and G_2. $G'\,G$ and $G_1\,G_2$ will represent the bottom of the gears. The rest of the sectional part can be drawn from the dimensions.

To show the shape of the teeth proceed as follows:

For the large gear, take N as a center, $N\,P'$ as a radius, and describe an arc. Choose a point H, and lay off $H\,H' = .48$ times the pitch = .48 inch, or the width of the tooth. With $N\,E'$ and $N\,D_1$ as radii, describe the addendum and root circles. Roll the describing circles upon the arc whose radius is $N\,P'$, and construct the tooth profile in exactly the same manner as in Fig. 4 of the plate entitled Profiles of Gear-Teeth, $Q\,H$ and $Q_1\,H'$ being the radii of the faces and flanks. To show the shape of the same tooth at C', draw $C'\,N'$ perpendicular to $O\,P'$, or, what is the same thing, parallel to $N\,P'$. With $N'\,C'$ as a radius, and N as a center, describe an arc. Draw $N\,H$ and $N\,H'$, and the distance between the points of intersection on the arc just drawn, measured on that arc, will be the pitch of the gear at the bottom of the tooth. With the same center,

and $N' E_1$ and $N' E_2$ as radii, describe arcs representing the addendum and root circles. Draw $N Q$ and $N Q_1$, also $Q H$ and $Q_1 H'$. Through K draw $K Q'$ parallel to $H Q$, and through K' draw $K' Q_2$ parallel to $H' Q_1$; the points of intersection Q' and Q_2 of these lines with $N Q$ and $N Q_1$ are the centers for the face and flank of the tooth at K and K'. Circles passing through these points concentric with N contain the centers of all the circular arcs forming the tooth profiles that may be laid off upon the arc whose radius is $N K$. The whole process is called **developing the teeth of bevel-gears.**

In the same manner construct the tooth curves for the pinion, using the same describing circles, $1\frac{1}{16}$ inches in diameter, and $M P'$, $M' C'$ as radii, instead of $N P'$ and $N' C'$.

To construct the other view, draw first the projection of the pinion. Draw the center line $m n$. Produce the lines $F F'$, $D B$, $P' P$, and $E A$ across the drawing, as shown. Choose a point S on $m n$ as a center, and draw a quadrant with a radius equal to the radius of the pinion, as $S P$. Project the points D and E upon $M O$ in D_2 and E_3. With S as a center, and the distances $E_3 E$ and $D_2 D$ as radii, describe quadrants to represent the tops and bottoms of the teeth, that is, the projection of the addendum and root circles of the pinion in Fig. 2. Since the whole pinion contains 16 teeth, the quadrant will contain 4; hence, divide the quadrant into 4 equal parts on the pitch circle to represent the centers of the teeth. Lay off on each side of the points of division distances $g e$ and $g b$, each equal to one-half the thickness of the tooth. On each side of the points of division on the addendum circle lay off $h f$ and $h c$, each equal to one-half the thickness of the top of the tooth $J K$, Fig. 1, measured on the addendum circle. On each side of the points of division on the root circle lay off $i d$ and $i a$, each equal to one-half the thickness of the tooth at the root, as $O P$, Fig. 1, measured on the root circle. Having now three points on each side of all the teeth to the right of the center line $m n$, project them upon the lines $E A$, $P' P$, and $D B$, produced as shown. For example, project f and c upon $E A$ in f' and c'; e and b upon $P' P$ in e' and b'; d and a upon $D B$ in d' and a'. Draw a curve through these points either by using an irregular curve

or by circular arcs. This remark also applies to the other curves shown in the quadrant.

The tooth curves in Fig. 1 must be drawn as accurately as possible, but those shown in Fig. 2, being oblique projections, are drawn to satisfy the eye, and no particular accuracy is required. To find the points on the tooth curves at the bottom of the pinion, describe a circle having a center O_2 upon $m\,n$, which shall be tangent to $P\,P'$, and have a diameter equal to $6.37'' =$ the diameter of the large gear. Through B' and A', Fig. 1, draw lines parallel to $O\,O_2$; also draw other lines through O_2 and the points d', f', c', etc., cutting the lines first drawn in d'', f'', c'', etc. Two points are considered enough in this case, as the curves are very short. They may be drawn in with the irregular curve in the same manner as the tops. The other teeth are drawn in a similar manner. Draw the middle tooth first. The left-hand half of the pinion is exactly the same as the right-hand half.

To draw the projection of the large gear, project the points E', D_1, L, and R upon the axis $O\,N$, in the points E_4, D_3, L_1, and R_1, and with O_2 as a center, and radii equal to $E_4\,E'$, $D_3\,D_1$, $L_1\,L$, and $R_1\,R$, describe circles to represent the addendum and root circles of the tops and bottoms of the teeth in Fig. 2. Divide the pitch circle into 20 equal parts to correspond with the number of teeth in the large gear, beginning with the point of intersection of the pitch circle with the center line $m\,n$. Lay off on each side of these pitch-circle divisions, distances equal to one-half the thickness of the teeth = one-half of $H\,H'$ in Fig. 1. By exactly the same method that was used to lay off the thickness of the teeth at the top and bottom on the quadrant, lay off the thickness of the top and bottom of the teeth on the addendum and root circles in Fig. 2. Draw the bottoms of the teeth in exactly the same manner as the bottoms of the pinion teeth were drawn.

All of the teeth of the large gear are alike in the projected view.

Bevel-gears are always measured according to their largest pitch diameter, as $P\,P'$ and $P'\,P_1$. If a bevel-gear were spoken of as 12 inches in diameter, it would be understood that the largest pitch diameter was 12 inches.

DRAWING PLATE, TITLE: GOVERNOR.

69. This plate shows a partial section and elevation of a **governor** of the Porter-Allen type. A belt driven from a pulley on the crank-shaft causes the pulley *A* to revolve, which in turn drives the bevel-gears; the bevel-gears drive the vertical shaft *B*, and cause the balls *C*, *C* to revolve. Owing to the centrifugal force generated by the balls, they tend to fly outwards and raise the weight *W*, which fits loosely on the shaft *B*. When the engine is running at its rated speed the balls *C*, *C* are 22 inches apart between their centers, or each is 11 inches from the center line *m n*. If the engine runs slower than its rated speed the centrifugal force becomes less, and the weight *W* causes the balls to move inwards; the weight *W* drops and forces down the lever arm *D*, which admits more steam to the cylinder, and increases the speed of the engine. If the engine runs faster than its rated speed the centrifugal force increases, raises the weight *W*, and lifts the lever arm *D*, which shuts off steam admitted to the cylinder, and decreases the speed of the engine. In both cases the other lever arm actuates the valve by means of mechanisms not shown.

To draw the governor as shown, draw the center line *m n* and the base line, and locate the top of the shaft. Then, draw all that part of the figure that is sectioned. The brass oil cup has a thread cut on its lower end, and is screwed in by means of the hexagonal shoulder. The tap bolt *F'* holds the plate *F'* in place. This plate can be removed so that the gears, bearings, etc. may be examined.

To draw the upper part (not sectioned) from the dimensions given, proceed as follows: Locate the center *O* of the arms $2\frac{3}{16}$ inches below the top of the shaft. Draw a horizontal line *H H*, $8\frac{3}{4}$ inches above the top of the body or sectional part, and mark off on it the point *Q*, $2\frac{1}{2}$ inches to the left of *m n*. With *Q* and *O* as centers, and radii of $13\frac{3}{32}$ and $16\frac{5}{8}$ inches, respectively, describe short arcs intersecting at *P*; *Q P* and *O P* are the center lines of the governor arms. The corresponding points on the other side are found in the same manner. Having located the points *O*, *P*, and *Q*, the rest of the drawing can

be completed without further description from the dimensions given. *I* and *K* are washers.

The upper end of the shaft has a long hole drilled in it to lubricate the bearing surface between the weight and the shaft. The lower end of the shaft turns in a brass bearing, and has two hardened steel convex disks between it and the bearing. These disks reduce the wear caused by the friction due to the weight of the shaft, arms, and weight *W*.

DRAWING PLATE, TITLE: BOILER SETTING—I.

70. This plate shows a front view of a **battery of three return tubular boilers,** one in elevation and the other two in section. When drawing this plate, reference must be made occasionally to the next plate, which is sent with it for the purpose of giving the student an opportunity of ascertaining some of the dimensions, and of obtaining a clear idea of how the sections are taken, and the reasons for drawing certain lines. Since both plates have the same title and are distinguished only by the numerals I and II, they will hereafter be referred to as I or II, as occasion may arise.

In II is shown a section taken on the vertical center line of the setting of one of the boilers shown in I, the boiler itself being shown in side elevation. Fig. 1 shows a front elevation of one of the boilers ; Fig. 2, a section taken through the smoke-box on the lines *s r* and *q p* ; and Fig. 3, a section on the line *s t*. (See II.)

71. To draw I, begin by drawing the main horizontal center line *m n* at a distance of about $7\frac{1}{2}$ inches from the bottom border line of the drawing ; locate the point *O*, the center of the boiler, in Fig. 2, on the horizontal center line *m n*, somewhere near the center of the sheet, and draw the vertical center line *s r* through it. Lay off points *O'* and *O''* in the main horizontal center line *m n*, at a distance of 6 feet $7\frac{1}{2}$ inches on each side of the vertical center line *s r*. Through these points draw the vertical center lines *q p* and *v t* of the boilers in Figs. 1 and 3, respectively.

Next lay off, above and below the main horizontal center line $m\,n$, the distances $n\,b = 3$ feet $5\frac{1}{4}$ inches and $n\,d = 6$ feet $7\frac{1}{4}$ inches, which are to be taken from II, and draw the lines $a\,b$ and $c\,d$, respectively. From the vertical center line $q\,p$ lay off to the right a distance of 3 feet $7\frac{3}{4}$ inches, and to the left a distance of 3 feet $3\frac{3}{4}$ inches, and draw the lines $d\,b$ and $f\,e$. With O' as a center, and one-half of 3 feet 9 inches as a radius, describe the inner circle of the smokebox doors, and complete them from the dimensions given. Then lay off the centers of the furnace doors, at a distance equal to 18 inches on each side of the vertical center line $q\,p$, and draw vertical center lines through them. Also, draw the horizontal center line of these doors at a distance of 3 feet 3 inches below the main horizontal center line $m\,n$. The student now has the location of the furnace doors, and should experience no trouble in completing them from the dimensions given. Having finished these doors, he should then draw in the ash-pit doors and complete the boiler front.

Some of the small boiler fixtures, such as the steam gauge, water column, water gauge, water-gauge cocks, etc., are not dimensioned, so as not to obscure the drawing by the use of too many lines and figures. They should be proportioned by the eye. This is the custom followed in the drafting rooms. On completing these he should draw in the smokestack and its base, then the dome, omitting the rivets. The dimensions of the dome can be obtained from Fig. 3 and II. The drawing of the rivets will be taken up later.

To draw Figs. 2 and 3, begin by drawing in the boilers with the tubes, brackets, and domes complete. There are 24 rivets around the upper edge of each dome. These may be drawn in their correct position as shown, by producing the center line $v\,t$ in Fig. 3 upwards, taking some point on this line as a center, and describing a circle having the same diameter as the dome. Divide this circle into 24 equal parts, using the vertical center line for the starting point, and project the points of division of the lower half of the circle downwards upon the horizontal center line of the rivets. The points thus projected upon this line will be the centers of the rivets. Only the rivet on the center

line $v\,t$ will be round in this view, all of the others being elliptical, and may be drawn free-hand. Then draw in the walls. The surfaces of these walls which come in contact with the fire and hot gases are lined with firebrick, and the walls proper are made of red brick. The ordinary red brick is sectioned in the same manner as cast iron, while the sectioning of the firebrick is a heavy line and a short broken line, alternately. Next, draw in the plates and rollers on which the boiler rests. These rollers are used to allow the boilers to expand and contract freely under the usual influences of alternate heat and cold.

Since Fig. 2 is a section taken through the smokebox on the lines $s\,r$ and $q\,p$, II, and the inside of the smokebox, except the top of it, is built up of firebrick in the shape of a frustum of a cone, as will be seen by referring to Plates I and II, the diameter of the smokebox on the line where the section is taken is smaller than the diameter of the boiler, and is equal to a radius $g\,h$ (see II), which measures 2 feet $1\frac{1}{2}$ inches. This accounts for part of the boiler being shown in dotted lines.

In I, the location of the holes receiving the pipes connected to the water column is shown by i and J, and the hole receiving the feed-pipe by k. Now draw in the smokestack, its base, and the frames of the furnace doors from the dimensions given, and complete this figure. In Fig. 3, draw in the safety valve and grate bars, obtaining some of the dimensions from II.

Draw in the buckstaves A and B and the tie-rods $l\,l$ and $l_1\,l_1$; also the buckstaves C, D, and E at the back of the boilers, shown by dotted lines, and the tie-rods u, u, u, etc. These rods are rectangular in cross-section and have round end pieces, so that they will admit of being threaded to receive the nut. Buckstaves are used for strengthening the walls of the boiler setting and preventing them from bulging outwards.

DRAWING PLATE, TITLE: BOILER SETTING—II.

72. In drawing this plate, reference must be made occasionally to the previous plate for some of the dimensions. Begin by drawing the main horizontal center line $m\,n$; then the shell

of the boiler from the dimensions given ; after which draw the center line $v\,t$ of the dome exactly in the center of the middle section of the boiler shell, and complete the dome. The rivets in the dome and boiler shell may be drawn in the same manner as explained in I.

To draw the curves representing the intersection of the dome with the boiler, locate the point v' on the center line $v\,t$ corresponding to the point v', in Fig. 3, Plate I ; and on the center line $v\,t$ of the dome in II, find by trial the point O, so that when it is used as a center, an arc may be passed through the point v' and the two points w, w. The radius of this arc will be 3 feet 3 inches. These dimensions should not appear on the student's drawing. The edge of the flange of the dome may also be described from the same center. It is not necessary to construct the true curve of the intersection of the dome and the shell, as drawn in Fig. 1 of the plate entitled Intersections and Developments.

Draw the yoke on the top of the dome, after which draw the brackets and safety valve from the dimensions given on I and II. Below the main horizontal center line $m\,n$, lay off a distance of 6 feet $7\frac{1}{4}$ inches, and draw the line $c'\,d'$, and above this line ($c'\,d'$) lay off the height h of the boiler setting $=$ 10 feet $\frac{1}{2}$ inch, and draw the line $a'\,b'$. On the main horizontal center line $m\,n$ lay off to the left from the front head of the boiler a distance of $15\frac{1}{4}$ inches, and draw the vertical line $e'\,e'$, after which complete the boiler front from the dimensions given, referring to I when necessary. On the same center line, lay off to the right from the back head of the boiler a distance of 24 inches, and draw the vertical line $f'\,f'$; after which complete the rear wall, and then draw the flue plate g'. Now draw in the grate bars, bridge, blow-off pipe, and smokestack, including the base, from the dimensions given, and, finally, the small fixtures, such as the water column and connections, steam gauge, water-gauge cocks, etc., also the feed-water pipe. No dimensions are given for these, and, therefore, they must be proportioned by the eye. Then draw in the buckstaves and tie-rods. The student should experience no difficulty in completing this plate.

TRACINGS.

73. In actual practice in the drawing room, it is necessary to have more than one copy of a drawing. It would be very expensive to make a finished drawing every time an extra copy was wanted, and, to avoid this, tracings and blue-prints are made. Any number of blue-print copies can be made from the same tracing. A complete pencil drawing is made first; then, instead of inking in as heretofore, a piece of tracing paper or tracing cloth of the same size as the pencil drawing is fastened to the board over the original drawing. The tracing paper or cloth being almost transparent, the lines of the drawing can be readily seen through it, and the drawing is inked-in on the tracing paper or cloth in the same manner as if inking-in a finished drawing.

Tracing paper is but little used in this country. It is easily torn, and cannot be preserved as well as tracing cloth. The two sides of the **tracing cloth** are known as the glazed side and the dull side; they are also known as the front and the back. The glazed side, or front, is covered with a preparation that gives it a very smooth polished surface; the back, or dull side, has very much the appearance of a piece of ordinary linen cloth. Either side may be used for drawing upon, but when the glazed side is used, care must be taken to remove all dirt and grease, otherwise the ink will not flow well from the pen. This can be done by taking a knife or a file and scraping or filing chalk upon the tracing cloth; then, take a soft rag of some kind—cotton flannel or chamois skin—and rub it all over the tracing cloth, being sure to rub chalk over every spot. Finally, dust the rag and remove as much of the chalk from the cloth as can be gotten off by rubbing with the rag. The finer the chalk powder is, the better. It is not usual to chalk the dull side, but it improves it to do so. The glazed side takes ink much better than the dull side, the finished drawing looks better and will not soil so easily, and it is also easier to erase a line that has been drawn on this side. Pencil lines can also be satisfactorily drawn on the dull side, and if it is desired to photograph the drawing, it is better to draw on this side. The

draftsman uses either side, according to the work he is doing, and to suit his individual taste, but if the glazed side is used, *it must be chalked.* The tracings are drawn in a manner similar to the finished drawings, the center lines, section lines, etc. being drawn exactly as previously described.

After having drawn the plate entitled Boiler Setting—II, the student should make a tracing of the plate entitled 5-inch Globe Valve.

BLUE-PRINTING.

74. Blue-printing is the process of duplicating a tracing by means of the action of light upon a sensitized paper. The following solution is much used for sensitizing the paper: Dissolve 2 ounces of citrate of iron and ammonia in 8 ounces of water; also, $1\frac{1}{4}$ ounces of red prussiate of potash in 8 ounces of water. Keep the solutions separate, and in dark-colored bottles in a dark place where the light cannot reach them. Better results will be obtained if $\frac{1}{2}$ an ounce of gum arabic is dissolved in each solution.

When ready to prepare the paper, mix equal portions of the two solutions, and be particularly careful not to allow any more light to strike the mixture than is absolutely necessary to see by. For this reason, it is necessary to have a dark room to work in. There must be in this room a tray or sink of some kind that will hold water; it should be larger than the blue-print, and about 6 inches deep. There should also be a flat board large enough to cover the tray or sink. If the sink is lined with zinc or galvanized iron, so much the better. There must be an arrangement like a towel rack to hang the prints on while they are drying. For the want of a better name, this arrangement will be called a print rack. The paper used for blue-printing should be a good, smooth, white paper, and may be purchased of any dealer in drawing materials. Cut it into sheets a little larger than the tracing, so as to leave an edge around it when the tracing is placed upon it. Place eight or ten of these sheets upon the flat board before mentioned, taking care to spread flatly one above another, so that the edges do not overlap. Secure the sheets to the board by driving a brad or

small wire nail through the two upper corners sufficiently far into the board to hold the weight of the papers when the board is placed in a vertical position. Lay the board on the edges of the sink, so that one edge is against the wall and the board is inclined so as to make an angle of about 60° with the horizontal. Darken the room as much as possible, and obtain what light may be necessary from a lamp or gas jet, which should be turned down very low. With a wide camel's-hair brush or a fine sponge, spread the solution just prepared over the top sheet of paper. Be sure to cover every spot, and do not get too much on the paper. Distribute it as evenly as possible over the paper, in much the same manner that the finishing coat of varnish would be put on by a painter. Remove the sheet by pulling on the lower edge, tearing it from the nail which holds it, and place it in a drawer where it can lie flat and be kept from the light. Treat the next sheet, and each succeeding sheet, in exactly the same manner, until the required number of sheets has been prepared.

Unless a large number of prints is constantly used, it is cheaper to buy the paper already prepared. It can be bought in rolls of 10 yards or more, of any width, or in sheets already cut and ready for use. There is very little, if anything, saved in preparing the paper, and better results are usually obtained from the commercial sensitized paper, since the manufacturers have machines for applying the solution, and are able to distribute it very evenly.

75. In Figs. 76 and 77 are shown two views of a printing frame which is well adapted to sheets that are not over $17'' \times 21''$. The frame is placed face downwards, and the back A is removed by unhooking the brass spring clips B, B and lifting it out. The tracing is laid upon the glass C, with the *inked* side touching the glass. A sheet of the prepared paper, perfectly dry, is laid upon the tracing with the yellow (sensitized) side downwards. The paper and tracing are smoothed out so as to lie perfectly flat upon the glass, the cover A is replaced, and the brass spring clips B, B are sprung under the plates D, so that the back cannot fall out. While all this is being done, the paper should be kept from the light as much

as possible. The frame is now placed where the sun can shine upon it, and adjusted as shown in Fig. 77, so that the sun's rays will fall upon it as nearly at right angles as possible. According to the conditions of the sky—whether clear or cloudy—and the time of the year, the print must be exposed from 3 to 15 minutes. The tray, or sink, already mentioned, should be filled to a depth of about 2 inches with clear water (rain water if possible). The print having been exposed the proper length of time, the frame is carried into a dark part of the room, the

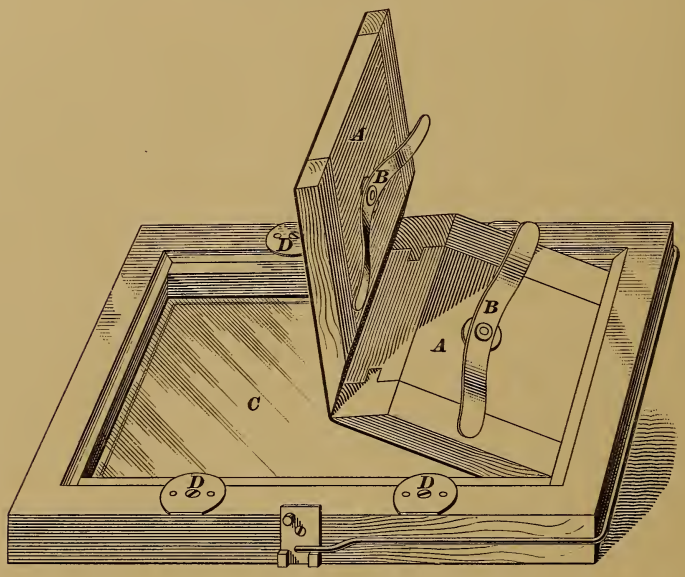


FIG. 76.

cover removed, and the print (prepared paper) taken out. Now place it on the water with the yellow side down, and be sure that the water touches every part of it. Let it soak while putting the next print in the frame. Be sure that the hands are dry before touching the next print. The first print having soaked a short time (about 10 minutes) take hold of two of its opposite corners, and lift it slowly out of the water. Dip it back again and pull out as before. Repeat this a number of times until the paper appears to get no bluer; then hang it by

two of its corners to dry on the print rack above spoken of. If there are any dark purple or bronze-colored spots on the prints, it indicates that the prints were not washed thoroughly on those spots. If these spots are well washed before the print is dried, they will disappear.

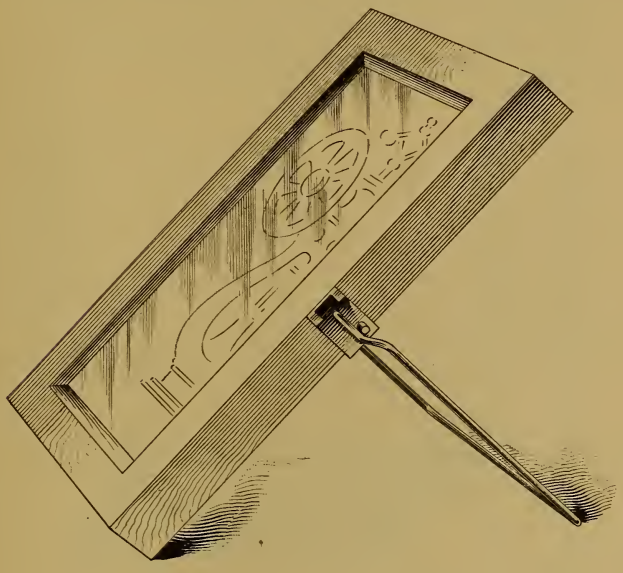


Fig. 77.

76. It is best to judge of the proper time of exposure to the light by the color of the strip of print projecting beyond the edge of the tracing. To obtain the exact shade of the projecting edge, take a strip of paper about 12 or 14 inches long and 3 or 4 inches wide. Divide it into, say, 12 equal parts by lead-pencil marks, and, with the lead pencil, number each part 1, 2, 3, etc. Sensitize this side of the paper, and, after it has been properly dried, place it in the print frame with the sensitized side and the marks and figures against the glass. Expose the whole strip to the light for one minute; then cover the part of the strip marked 1 with a thin board or anything that will prevent the light from striking the part covered. At the end of the second minute, cover parts 2 and 1; at the end of the third

minute, parts 3, 2, and 1, etc. When twelve minutes are up, part 1 will have been exposed one minute; part 2, two minutes,

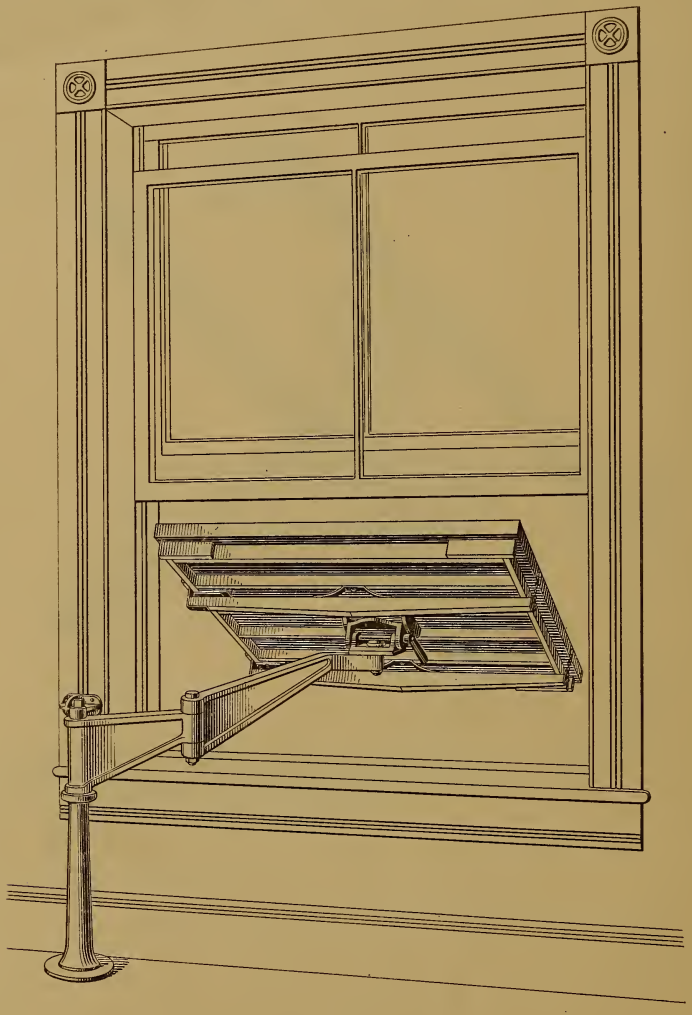


Fig. 78.

etc., part 12 having been exposed twelve minutes. Remove the frame to a dark part of the room, and tear the strip so as to divide it into two strips of the same length and about half the

original width. Wash one of the strips as before described, and when it has dried, select a good rich shade of blue, neither too light nor too dark ; notice the number of the part chosen, and it will indicate the length of time that the print was exposed. Examine carefully the corresponding part of the other strip, and the correct color of the edge of the print projecting beyond the tracing is determined. All prints should be exposed until this color is reached, no matter how long or how short the time may be ; then they should be immediately taken out and washed.

In Fig. 78 is shown a patented frame which can be shoved out of the window and adjusted to any angle. When not in use, it can be folded up against the wall, and occupies but little space. It is made in different sizes from $16'' \times 24''$ to $48'' \times 72''$. It is one of the best frames in the market, and is placed in such a position relatively to the window that the window can be lowered to the top of the main arm, when it is desired to keep out the cold during the winter.

DRAWING PLATE, TITLE: SIX-HORSEPOWER HORIZONTAL STEAM ENGINE.

77. Instead of making a finished drawing of this engine, as in the previous plates, from an exact copy, the student is given the rough sketches of the details of a **six-horsepower horizontal steam engine,** with full dimensions marked upon them ; from these he is expected to make a general pencil drawing of the engine in two views—a plan and a side elevation.

The pencil drawing should then be traced according to the directions previously given. The details are not drawn to scale, but are fully dimensioned. In order to draw the engine to as large and as convenient a scale as possible, it is necessary to make this tracing a trifle larger than the plates which have preceded it. The size over all will be $14\frac{1}{2}'' \times 18\frac{1}{2}''$, with the usual border line $\frac{1}{2}$ inch from each edge all around.

That the student may have a good idea of what he is expected to do, a greatly reduced cut of the general drawing is also given him. All dotted lines indicating parts not seen have been

omitted, in order to simplify the work. The scale to be used is 3 inches = 1 foot.

Draw the center lines $m\,n$, $p\,q$, $r\,s$, and $t\,v$. Draw the side elevation of the bed-plate with the bearing caps in position, from the dimensions given on the detail sketches, taking care to make those parts which are likely to be hidden by the fly-wheel, eccentric rod, etc., light so that they may be easily erased before tracing. The drawing may be traced without removing the unnecessary construction lines, but it is better to do so, since it lessens the liability of inking-in lines which will have to be erased from the tracing.

Draw the plan of the bed-plate with the bearing caps, studs and nuts, foundation-bolt holes, etc., shown in their proper places and positions. The different curves of the bearing caps in the plan should be constructed by projecting points from the view shown in the side elevation. In actual practice in the drawing room, three or four of the principal points (those which mark the limits) would be located and the curves sketched in free-hand, they being inked-in on the tracing by aid of an irregular curve. In such cases the draftsman has a good idea of the shape of the curves, owing to previous practice in drawing them. When drawing in the curves formed by the opening in the bed-plate, shown in this view, the student must exercise his own judgment regarding their shape, taking care not to get them too straight. The general drawing gives a good idea of their proper curvature.

Returning to the elevation, draw the crank and crank end of the connecting-rod in the position shown in the general drawing. With the center of the crank-pin as a center and a radius equal to the length of the connecting-rod between its centers (obtained from the detail sketch), describe an arc cutting the center line $p\,q$ at a point which will be the center of the cross-head pin. Draw the cross-head, obtaining the dimensions from the detail sketch. Complete the connecting-rod in both views and draw the piston rod 1 inch in diameter. Draw both views of the cylinder with the nuts and the steam pipe in their proper position, getting all dimensions from the detail sketches.

Draw the center line of the valve stem in the plan view, and

draw the stuffing-box, valve stem, valve-stem slide and its guide in both views. In order to determine the position of the valve-stem slide, it is necessary to locate the center of the eccentric. Referring to the general drawing, it is seen that the eccentric is on the dead center farthest from the cylinder. The offset of the eccentric is given as $\frac{7}{8}$ inch in the detail sketch; hence, when in this position, the center of the eccentric strap will be situated $\frac{7}{8}$ inch to the right of the crank-shaft center on the line $p\,q$. With this point as a center and a radius equal to the distance between the centers of the eccentric strap and the hole in the stub end of the eccentric rod (see detail sketch), in this case 2 feet $4\frac{1}{8}$ inches, describe an arc cutting the center line $p\,q$ in O; O will be the center of the pin on the valve-stem slide, which may be completed by aid of the detail sketch. Complete the drawing of the eccentric, eccentric strap and eccentric rod in both views.

Finally, draw in the band-wheel and fly-wheel (see general drawing for position). The fly-wheel will be of the same diameter as the band-wheel, but only 3 inches wide.

The pencil drawing is now completed. Before beginning to trace, erase those lines which are not to be inked-in. This is not necessary, but it is better to do so, since it avoids confusion and lessens the liability of making mistakes. Some draftsmen prefer to redraw a portion of those parts which are to be inked in with a somewhat softer pencil, and leave the light construction lines on the drawing rather than erase them; in some cases, this saves time.

The preliminary directions for tracing a drawing have been given previously. First, trace the side elevation, beginning with the fly-wheel, and then as much of the connecting-rod, eccentric, and eccentric rod as can be seen. Trace all those parts of the bed-plate, cylinder, valve stem, stuffing-box, etc. that are seen. Then trace the plan view, letter the drawing, and draw the border lines. There will be no plate number for this tracing, but the student's name, class number, and the date of completion will be put on as before.

The student should exercise particular care to have every dimension scale exactly the size given in the detail sketches.

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